May 1979

RESEARCH NOTE RM-369

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Effects of Watering Treatments on Germination, Survival, and Growth of Ponderosa Pine: A Greenhouse Study

Daniel L. Noble, Carleton B. Edminster, and Wayne D. Shepperd[1]

Amount and distribution of water from 0.0 to 2.0 inches per month (0.0 to 5.1 cm) affected germination, survival, and growth of ponderosa pine seedlings. Germination was less variable when water was applied once during the month than when water was evenly distributed. Seedling survival and growth was best when seedlings received 1 inch or more of water evenly distributed throughout the month.

Keywords: *Pinus ponderosa*, plant physiology, seed germination

Ponderosa pine (*Pinus ponderosa* Laws.) is the most important pine species in western North America (Harlow and Harrar 1958) and is a major component of the Montane Zone in central Colorado. This zone, at elevations from about 6,500 to 9,400 feet (1,970-2,850 m), is the first forested belt above the plains on the east side of the Colorado Rockies (Miller and Choate 1964). Altitude limits vary locally with latitude, aspect, and soil depth.

Ponderosa pine forests are important for timber, forage, water, esthetics, recreation, and wildlife habitat. Successful regeneration following disturbances is critical to the silviculture and management of these forests. Although successful regeneration of these forests may be possible (Myers 1974, Pearson 1950), more information is needed on the effects of environmental factors on natural regeneration.

According to Pearson (1950) amount and distribution of precipitation during the growing season are major factors influencing regeneration success. Hayes (1965) also concluded that inadequate moisture is a common obstacle to regeneration east of the Sierra-Cascades. The time needed for germination and subsequent establishment of ponderosa pine seedlings has been observed to vary with precipitation conditions, both in central Colorado (Myers 1974) and in the southwest (Schubert et al. 1970).

The studies reported here concern the effects of amount and distribution of precipitation

[1]Ecologist, Mensurationist, and Associate Silviculturist, respectively, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.

during the growing season on ponderosa pine regeneration success and were made under controlled greenhouse conditions to supplement field observations. Germination, initial survival, and early growth of seedlings were compared under watering treatments selected to represent precipitation patterns likely to occur on the Manitou Experimental Forest in central Colorado.[2]

Methods and Materials

Seed Source

The seed used was western ponderosa pine seed, collected in 1974 from the San Isabel National Forest, Hayden Creek drainage, at an elevation of 8,000 feet (2,438 m). The seed had been stored at 4° C. Average laboratory germination prior to the study was 68%.

Soil and Seedling

Forest soil from 7,800 feet (2,377 m) elevation on the Manitou Experimental Forest was used. It is a coarse sandy-loam developed from Pikes Peak granite and covers much of the Experimental Forest (Marcus 1973, Retzer[3]). Moisture holding capacities at 1/3 and 15 bars, determined in the laboratory, were approximately 24 and 13%, respectively. The soil was screened through 4-mesh hardware cloth, thoroughly mixed, placed in pots, 7 inches (18 cm) deep and 6 inches (15 cm) in diameter, and soaked to saturation twice daily for 3 days. Twenty seeds were then sown on the surface of the soil in each pot. All pots were again soaked to insure soil moisture near saturation before watering treatments were begun. A total of 150 pots were prepared.

[2]USDA Forest Service weather records for a 35-year period (1941-75) from the Manitou Experimental Forest, Colorado (records on file at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.) indicate that average precipitation for the months May and June (critical months for germination and initial seedling establishment) is 1.90 and 1.65 inches (4.8 and 4.2 cm), respectively. Precipitation for these months, generally ranging from 0.14 to 5.05 inches (0.4 to 12.9 cm) per month, is most likely to fall in either several small storms of 0.25 inch (0.6 cm) or less, or in one or two larger storms.

[3]Retzer, John L. 1949. Soils and physical conditions of Manitou Experimental Forest. 18 p. (Unpublished report on file at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.).

Experimental Design and Treatments

The study consisted of two experiments. Pots received 0.0, 0.5, 1.0, 1.5, or 2.0 inches (0.0, 1.3, 2.5, 3.8, or 5.1 cm) of water monthly. In experiment A the water was evenly distributed throughout the month in applications of 0.25 inch (0.64 cm). In experiment B pots received the assigned monthly level of water in one aplication. Each experiment was arranged in a randomized block design with 15 replications.

Greenhouse Environment

The environment in the greenhouse at Fort Collins, Colo., was maintained as close as possible to average field conditions during the growing season on the Manitou Experimental Forest. Air temperatures were 70° F (21° C) day and 40° F (4° C) night. The photoperiod was 16 hours of natural and artifical light. The transition period of temperature changes coincided with photoperiod. Relative humidity was varied from 20-30% (day) to 70-80% (night). However, high light intensities—up to 12,000 footcandles (129,000 lx)—associated with openings in forest cover on the Manitou Experimental Forest could not be reached in the greenhouse. The normally lower light intensity at 5,000 feet (1,524 m) elevation was further reduced by the greenhouse glass, so that light intensity varied from 3,000 footcandles on cloudy days to about 5,000 footcandles on clear days.

Measurements and Analyses

Number of germinating seeds, number of surviving seedlings, and cause of mortality were recorded twice weekly. At the end of 20 weeks soil was carefully washed from the roots of all live seedlings and the top height and root length measured to the nearest millimeter. Seedlings were oven dried for 24 hours at 100° C and weighed to the closest 0.1 mg.

Germination and survival were expressed as a percent of the number of seeds sown per pot; top height, root length, and total seedling dry weights were means of all surviving seedlings in a pot. Differences due to treatments were tested for significance by analyses of variance with arc sine transformations for percentage data. Tukey's method of simultaneous con-

fidence intervals was used to determine which treatment differences were significant (Graybill 1976).

Results

Germination

Average germination under the treatments where water was evenly distributed ranged from 26% for the 0.0 water to 46% for 2.0 inches of water. Although significant differences in germination occurred between watering treatments in this experiment, definite trend was not observed (fig. 1). Likewise, where water was applied once a month (experiment B), germination was not significantly affected by amount, varying only from 27% at the 0.5 inch per month to 31% at the 1.5 inches per month. Germination for the 0.0 and 2.0 inch levels was 29% (fig. 1).

Length of Germination Period

The length of time over which seedlings emerged was affected little by either the distribution or amount of water received. In both experiments germination began in about 14 days and was generally completed 49 days after sowing. In experiment B some delayed germination occurred following the third application of water (fig. 2).

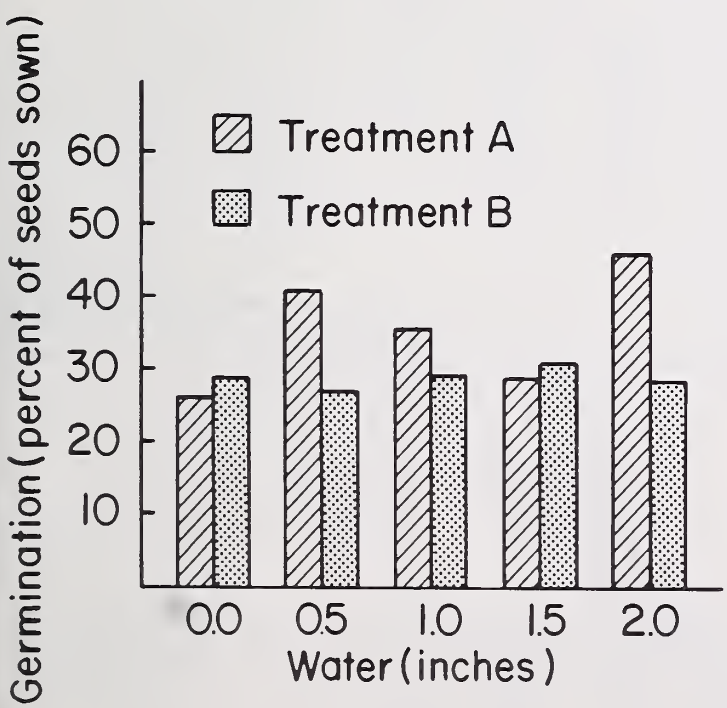


Figure 1.—Total germination in relation to watering treatments—treatment A (water distributed during the month), and treatment B (water applied once a month).

Seedling Survival

Number of seedlings surviving after 20 weeks was related to both amount and distribution of water. When water was evenly distributed, 1.0 inch or more of water was required to sustain significant survival ($0.05 < \alpha \leq 0.10$). Survival varied from 14% at 0.5 inch per month to 43% at 2.0 inches per month (fig. 3) in this experiment. When water was applied once a month, survival percentages at all water levels were low and were not significantly different, only varying 16-20% (fig. 3).

Causes of Mortality

In experiment A drought was the principal cause of mortality at all levels of watering (table 1). Damping-off was an important cause of mortality at 1.5 inches or more. At the higher water levels (1.0 in or more), losses also occurred from failure to establish. The radicle emerged from the seedcoat and did not develop further, either because the seeds could not imbibe sufficient water for the radicle to penetrate the soil or seeds did not have enough germination vigor to complete establishment.

In experiment B drought was the major cause of mortality at all treatment levels (table 1). Seedling losses from damping-off were minor even at 1.5 and 2.0 inches. However, mortality from failure to establish was important at 1.0 inch or more of water.

Seedling Growth

Seedling biomass, top height, and root elongation were not significantly related to amount of water in either experiment. In experiment A plant growth data for 0.5 inch were not analyzed because of poor survival.

Because the two water distribution methods were separate experiments, seedling growth could not be compared statistically. However, there are apparent differences, since seedlings from the evenly distributed watering experiment were considerably heavier and had slightly longer tops and roots than seedlings watered once a month (table 2).

Discussion and Conclusion

The greenhouse environment was more favorable to germination, survival, and growth than are natural conditions. It is difficult, therefore, to extrapolate results from the greenhouse to the field. Nevertheless, certain inferences can be drawn from these experiments concerning the effects of amount and distribution of precipitation on natural regeneration of ponderosa pine in the central and southern Rocky Mountains.

Assuming adequate seed is available, along with favorable seedbed conditions, only slightly more seedlings emerge with frequent showers than with one or two larger storms. When soils are initially saturated, the amount of subsequent precipitation has no clear effect on germination, regardless of rainfall frequency (fig. 1). Most germination is completed in 49 days whether precipitation is well distributed or occurs in only one or two storms (fig. 2).

Seedling survival is strongly affected by both distribution and amount of precipitation. At least 1 inch of evenly distributed precipitation is needed monthly before seedling survival could be considered adequate and additional rainfall may further increase survival. Conversely, seedling survival is inadequate with infrequent precipitation even at 2 inches per month (fig. 3).

The distribution of precipitation can affect seedling growth. Seedlings receiving 1.0 or more inches of well distributed precipitation per month were consistently heavier, taller, and had longer roots than seedlings receiving the same amount of rainfall once per month (table 2). However, the magnitude of seedling growth in the greenhouse may not be comparable to field-grown seedlings. Average top height was about the same as that found by Jones (1971) for field grown first-season seedlings but root length was about 1-1/3 times greater.

In this study only precipitation has been considered. Regeneration success is affected by many environmental factors and their interactions, which must be evaluated before the effectiveness of a single factor such as precipitation can be fully analyzed. It is apparent, however, the amount and distribution of precipitation can be a major factor in the establishment of ponderosa pine seedlings.

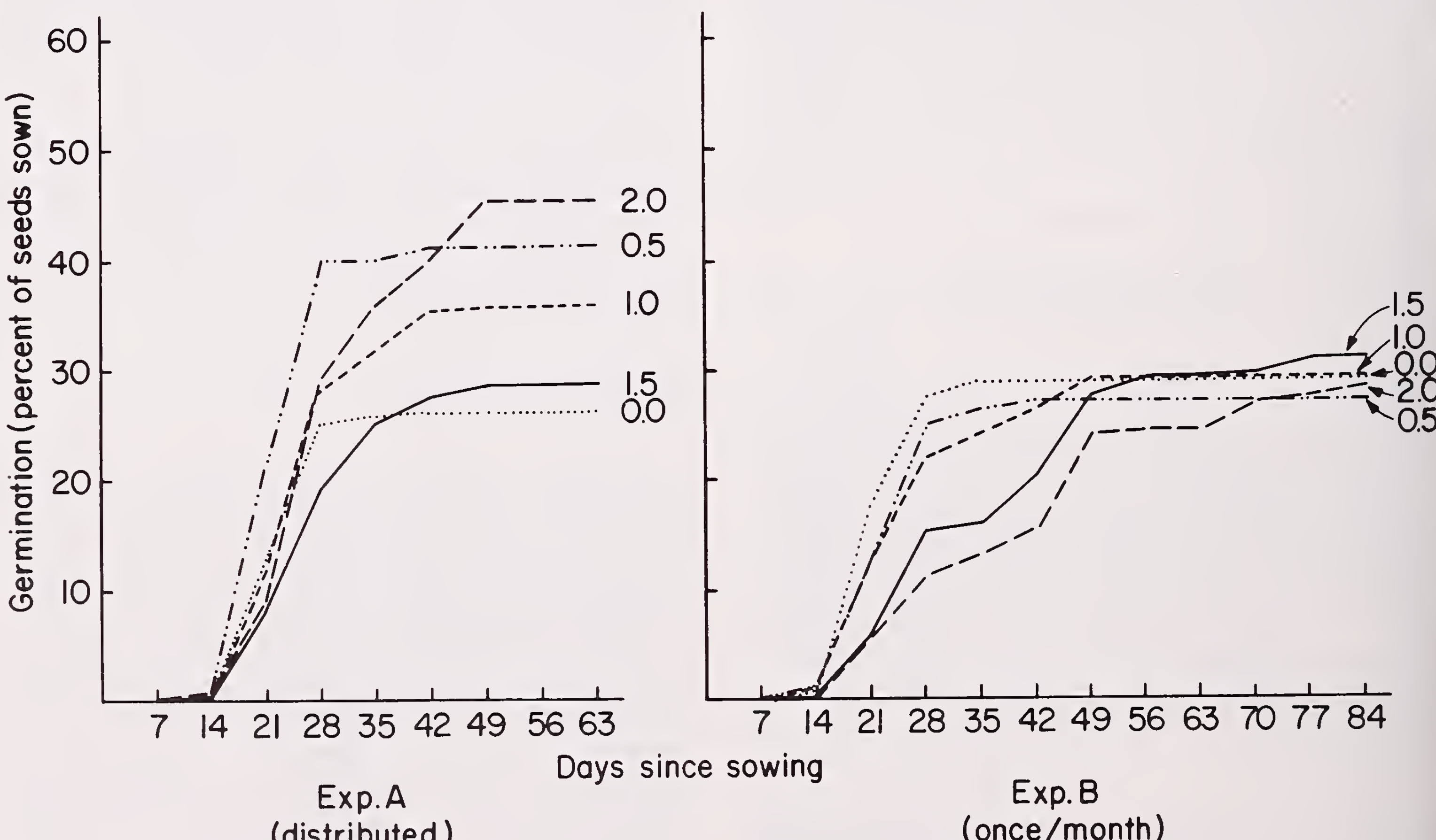


Figure 2.—Length of germination period in relation to water amounts and distribution.

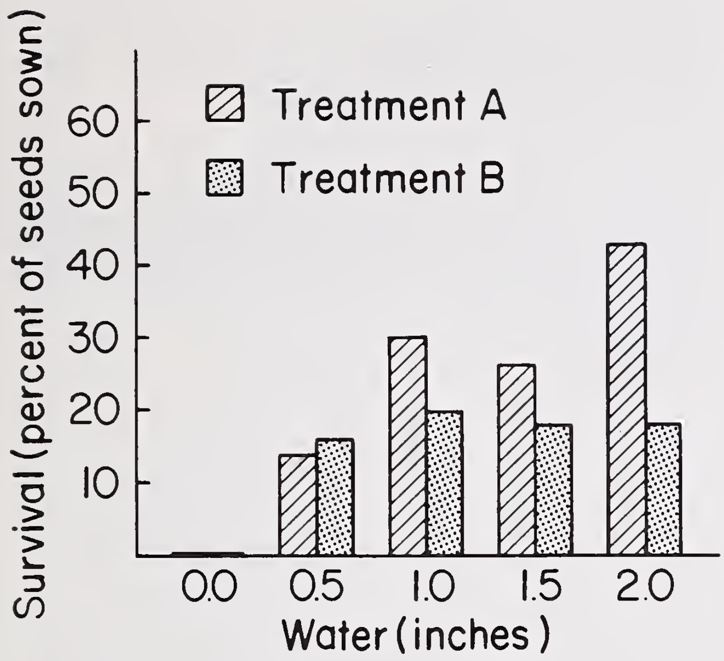


Figure 3.—Seedling survival after 20 weeks in relation to watering treatments—treatment A (water distributed during the month), and treatment B (water applied once a month).

Literature Cited

Graybill, Franklin A. 1976. Theory and application of the linear model. 704 p. Duxbury Press, North Scituate, Mass.

Harlow, W. M., and E. S. Harrar. 1958. Textbook of dendrology. McGraw-Hill Inc. N.Y. 561 p.

Hayes, G. Lloyd. 1965. Providing for optimum regeneration in the logging plan—east side. West. Refer. Coord. Comm. [Vancouver, B.C., Dec. 1965] Proc. 1965:6-9. West. For. Conserv. Assoc., Portland, Oreg.

Jones, John R. 1971. Mixed conifer seedling growth in eastern Arizona. U.S. For. Serv. Res. Pap. RM-77, 19 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Marcus, Steven R. 1973. Geology of the Montane Zone of central Colorado—with emphasis on Manitou Park. USDA For. Serv. Res. Pap. RM-113, 20 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Table 1.—Percent total mortality, by cause, of greenhouse-sown ponderosa pine seedlings (A) watered at predetermined intervals during the month, and (B) watered once a month

Monthly amount of water		Drought		Damping-off		Failure to establish		Other causes	
		A	B	A	B	A	B	A	B
(in)	*(cm)*								
0.0	0.0	98.7	95.4	0.0	0.0	1.3	4.6	0.0	0.0
0.5	1.3	96.1	93.5	1.3	0.0	2.6	6.5	0.0	0.0
1.0	2.5	62.5	58.6	0.0	0.0	18.8	37.9	18.7	3.5
1.5	3.8	42.8	75.6	28.6	4.9	14.3	19.5	14.3	0.0
2.0	5.1	60.0	80.6	30.0	6.5	10.0	12.9	0.0	0.0
Average		90.3	84.5	3.2	1.8	4.3	13.2	2.2	0.5

Table 2.—Average growth of greenhouse-grown ponderosa pine seedlings (A) watered at predetermined intervals, and (B) watered once a month. (Means were statistically homogeneous at $\alpha = 0.05$)

Monthly amount of water		Dry weight		Seedling height		Root length		Root/shoot ratio	
		A	B	A	B	A	B	A	B
in	*cm*	*mg*		*mm*		*mm*			
[1]0.5	1.3	(41.1)	63.9	(42.8)	46.8	(154.7)	162.8	(3.64)	3.51
1.0	2.5	104.4	87.7	52.2	51.4	184.8	178.5	3.53	3.46
1.5	3.8	147.8	88.0	53.2	49.2	196.0	189.2	3.73	3.85
2.0	5.1	142.0	84.5	53.6	49.2	180.4	174.2	3.38	3.53
Average		114.4	81.2	51.1	49.2	180.8	176.2	3.56	3.59

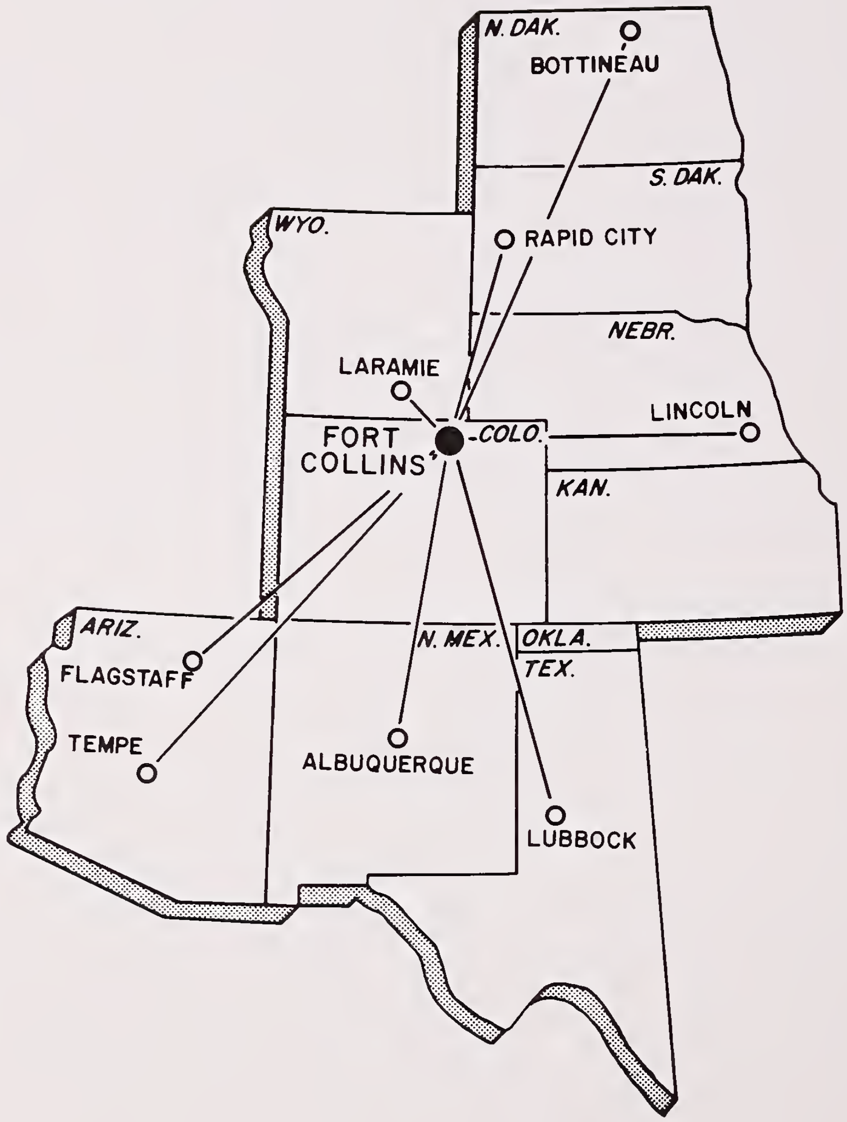
[1]In experiment A survival at the 0.5 inch water level was inadequate for analysis; data are included for general information.

Miller, Robert L., and Grover A. Choate. 1964. The forest resource of Colorado. USDA For. Serv. Resour. Bull. INT-3, 54 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Myers, Clifford A. 1974. Multipurpose silviculture in ponderosa pine stands of the Montane Zone of central Colorado. USDA For. Serv. Res. Pap. RM-132, 15 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pearson, G. A. 1950. Management of ponderosa pine in the southwest. USDA For. Serv. Agric. Monog. No. 6, 218 p.

Schubert, Gilbert H., L. J. Heidmann, and M. M. Larson. 1970 Artificial reforestation practices for the southwest. USDA For. Serv. Agric. Handb. 370, 25 p.


N. DAK.
BOTTINEAU
S. DAK.
RAPID CITY
WYO.
NEBR.
LARAMIE
LINCOLN
FORT COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
LUBBOCK